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ANALYSIS

Policy options for afforestation in Flanders

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ABSTRACT

This paper analyses current and alternative afforestation policy instruments in Flanders. First we select forest sites that maximize net social benefits given a constraint on the total area of new forests and then we select policy instruments that yield this optimal combination of sites. For each policy option, we calculate the associated costs for landowners and government as well as net social benefits for society. Our empirical illustration shows that the welfare gain is considerable if the afforestation subsidy is conditioned on an objective criterion rather than a case-by-case approach. Our results also show that it is worthwhile to consider alternative policy instruments, such as auctions, not previously used in Belgian legislation.

1. Introduction

Stimulating afforestation is one of the challenges of environmental policy in Flanders as in many other countries. In order to optimally design the afforestation policy, it is important to carefully consider the location of the newly created forests. Through a heuristic approach we analyse how to select the forest sites that maximize net social benefits given a constraint on the total area of new forests. These net social benefits include timber yield, hunting, ecosystem, recreation and non-use values minus planting and management costs and opportunity costs of foregone agricultural production. They are the result of subtracting all relevant costs from all relevant benefits for all affected parties in Flanders (Pearce et al., 2006). This is in our opinion a crucial step that is missing in the current Flemish afforestation policy, which implicitly assumes that any forest is a desirable forest. It is, however, clear that not all forests have the same per hectare value. Depending on its size and type as well as the distance to other forests and city centres, the increase in welfare brought about by the new forest can differ greatly. This paper analyses current and alternative afforestation policy instruments in view of the 10,000 ha afforestation goal of the Flemish government.

The current afforestation policy is based on three pillars: the acquisition of land by the Flemish government, the acquisition of land by local authorities, and subsidies for private landowners. However, this policy is not likely to yield the optimal location of the new forests and thus the highest social value for several reasons. Firstly, the government only buys less productive (farm)land or land that becomes available on the market, e.g. because of the retirement of its owner. Secondly, subsidies are available for all landowners who meet the requirements and, therefore, the regulator cannot predict who will use them. Locational aspects seem to be of minor importance. This implies that one already fairly wooded region could potentially increase its forest cover to a much larger extent than scarcely wooded areas, such as highly urbanized areas with a high need for recreation opportunities. This could also imply the creation of multiple small forests of each only a few hectares and thus less valuable from both an ecological and a recreational point of view. Finally, the policy is likely to be expensive for the government.

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Since the optimality of the current policy is questionable, we suggest alternative policies and test these in a real life example. In our opinion, a first essential step in improving the Flemish afforestation policy is the selection of the optimal location of a set of new forests. The emphasis lies on the optimal spatial allocation of these new forests from a benefit–cost perspective given the area constraint that cannot be met by creating one single new forest. We also include the negative externalities associated with the manure deposition policy when farmland is used for spreading manure by other farmers.

Once the optimal location of new forests is found, we investigate several different policy scenarios and check whether they can yield this optimal location. We also calculate the associated costs for landowners and government as well as net social benefits for society. Our results allow us to formulate policy recommendations and show that it is worthwhile to consider alternative policy instruments not previously used in Belgian legislation. For example, auctions for afforestation projects can be used to decrease the costs for the government associated with a subsidy system.

In Section two we describe the current afforestation policy in Flanders. In Section three we model land use decisions. Section four describes methodological issues regarding the selection of forest sites and the selection of an efficient policy instrument. Section five provides an overview of the data. In section six we present and discuss the results for the different policy options and compare them to the optimal and the current situation with a realistic example.

2. Current afforestation policy

The Flemish region is characterized by low forest cover (<10% of the land area) and a high population density index (approximately 400 inhabitants per km^2). In Flanders, the Long-Term Regional Forest Plan[2] (LTRFP) assumes a forest cover of 12% by the year 2010 (ABG, 2003). This target is very ambitious and unlikely to be met in time. The Land use Structure Plan of Flanders[3] (LSP) has identified the policy options for the realization of new forests or forest extensions of 10,000 ha by 2007. The Flemish Government is assumed to take a leading role in the realization of this afforestation goal but local administrations and the private sector have responsibilities as well. In this paper, we only discuss subsidy schemes for private landowners, in particular farmers, and the purchasing policy of the Flemish government.

Since the 10,000 ha goal was set, approx. 206 ha of new forests have been created per year while 126 ha of existing forest has been deforested each year (Dumortier et al., 2005). This implies that at the current rate it will take the government 127 years to reach the policy target.

The LSP does not give any guidelines as to the exact location of the new forests. On the qualitative level, the LSP indicates that ecological forest extension should primarily be realized close to existing forests, as a buffer (e.g. between a residential area and an industry zone), or in view of nature development or proximity of urban areas in order to serve as many potential recreationists as possible.[4]

2.1. Subsidy schemes for farmers

In order to implement European directives, the Flemish government worked out a subsidy scheme for the afforestation of farmland.[5] Within the framework of the EU Regulation 1257/99 on the support for rural development, support may be granted to private persons or administrations. More details on the European forest policy can be found in, among others, Bendz (2004) and Pülzl (2005).

The conditions that need to be fulfilled for a Flemish farmer to apply for a subsidy are:

– the parcel should be exploited as farmland in the 5 years prior to the application
– at least 0.5 ha of farmland should be forested
– no deforestation of multifunctional forests for at least 25 years; afterwards the land can only be deforested within the terms of the Forest Decree (Bosdecreet of 13 June 1990)
– plantings of poplar should remain for at least 15 years; afterwards the land can be re-used for farming unconditionally.

A summary of afforestation subsidies for farmers is given in Table 1. We make a distinction between poplar and deciduous trees.

2.2. Purchasing policy of the Flemish Government

Forest purchases within the next 40 years will take place within the framework of the LTRFP. The goals of this plan in terms of forest extension and the creation of new forests are set taking into account the current forest cover and several criteria such as multifunctionality, fragmentation, urban forests and biodiversity. The purchase policy aims at extending the forest area in Flanders by an average of 625 ha per year until 2040. Forests are only purchased by the Flemish Government when a substantial surplus value is created. Also, purchasing of land currently used by economically sound farms is avoided.

3. Modelling land use decisions

First, we formally describe the decision process of landowners and government. Landowners cultivate their land so that their private income is maximised. The government looks at the broader picture and maximises the total net benefit of land use.

[2] The Long-Term Regional Forestry Plan is a sectorial plan, in which the basic framework of the regional afforestation policy is identified for the future.

[3] The Land use Structure Plan of Flanders allows the Flemish Government to plan sustainable land use. Its main goals are to improve the general quality of life in urbanized areas and to strengthen the open space structures.

[4] The plan assumes that – emphasizing recreation – 1 ha of woodland is needed per 100 inhabitants.

[5] See ABG (2003) for a detailed discussion of the subsidy schemes.

Table 1 – Subsidies for afforestation of farmland (Euro per ha and per year unless mentioned otherwise)

	Poplar	Deciduous trees
Planting: basic subsidy	850	1500[a]–3700[b]
Planting: undergrowth	500	500
Planting: border (bushes or deciduous trees)	100 per 100 m	100 per 100 m
Maintenance	1100	1750
Supplement 1: land in forest or forest extension area (according to LSP)	250	250
Supplement 2: recommended origin (native species)	250	250
Income compensation	375 for 5 years	500 for 20 years for native tree species, 375 for 5 years otherwise

[a] Wallnut, false Acacia, American Oak, sweet Chestnut.
[b] Summer Oak, Winter Oak; for other native deciduous tree species one receives 2000, 2500 or 3000 €/ha. For a complete list see ABG (2003).

3.1. *Land use decisions of landowners*

We assume that each plot of land is owned by one farmer and that land use decisions concern the plot as a whole. Landowners are assumed to be risk neutral. In order to clearly understand the landowners' reaction to specific policies, we explicitly model their decision process (Latacz-Lohmann and Van der Hamsvoort, 1997; Kaplan et al., 2004; Castagnini et al., 2004). We assume that landowners choose the land use j ($j=0$ for agriculture; $j=1$ for a multifunctional forest; $j=2$ for a poplar forest) which maximises private net benefits Y_{ij} from the land parcel i. This income can differ for each plot depending on its characteristics and its landowner, and it consists of the sum of expected gross income from agriculture (Y^a_{ij}), agricultural (s^a_{ij}) and afforestation subsidies (s^f_{ij}), income from hunting (Y^h_{ij}) and timber (Y^t_{ij}), minus the manure disposal costs (C^m_{ij}), planting and management costs (C^p_{ij}) and taxes (t_{ij}). Formally the objective function of the owner of plot i is:

$$\max_j Y_{ij} = Y^a_{ij} + s^a_{ij} + s^f_{ij} + Y^h_{ij} + Y^t_{ij} - C^m_{ij} - C^p_{ij} - t_{ij}. \quad (1)$$

Landowners look at income after subsidies (e.g. EU agricultural subsidies) since this is what interests them. Flanders is a small open economy and as such does not influence world prices of agricultural produce. It also does not influence the level of the EU subsidies. Both the government and the farmers can thus take the EU agricultural policy as given. A recent overview of the European agri-environmental policy can be found in Latacz-Lohmann and Hodge (2003). In Section 5.1 we discuss the Flemish manure policy and the way we model fertilization decisions made by landowners.

3.2. *Land use decisions of the government*

The government wants to maximise the net social benefit accruing from land use in the region. Using a utilitarian approach (Sandmo, 2000), net social benefit consists of three terms: the income to landowners, the value of the land to society and the cost of financing the chosen policy. The regulator chooses the optimal land use for each plot, i.e. x_{ij} (=1 if land use j on plot i;else=0) is selected, in order to maximise

$$\sum_i Y_{ij}x_{ij} + \sum_i x_{ij}[V^R_{ij} + V^E_{ij} + V^{NU}_{ij}] + \mathrm{MCPF}\left[\sum_i x_{ij}\left[t_{ij} - s^f_{ij}\right]\right]$$

$$\text{s.t. } 150 \le \sum_i [x_{i1} + x_{i2}]A_i \le 200$$

$$\sum_j x_{ij} = 1 \quad (2)$$

with V^R_{ij} the recreation value of plot i under land use j, V^E_{ij} the ecosystem value of plot i under land use j, V^{NU}_{ij} the non-use value of plot i under land use j, MCPF the marginal cost of public funds[6] and A_i the surface area of plot i. Note that the Flemish government does not include agricultural subsidies into its objective function. We also do not consider the issues of irreversibility and uncertainty (Arrow and Fisher, 1974; Dixit and Pindyck, 1994) which might be relevant in an afforestation setting and which can create a quasi option value and add additional costs to afforestation.

The government faces an area restriction: only combinations, which yield a wooded area of at least 150 and at most 200 ha, are considered.[7] The second restriction to the optimisation problem (Eq. (2)) specifies that each parcel of land can only have one type of use. The land use combination that maximizes total net social benefit given these restrictions is called the optimal location of forests in the remainder of the text.

4. Methods

We evaluate the Flemish afforestation policy and determine which changes can improve welfare. First, we have to select those forest sites that maximize net social benefits taking into account the decision behaviour of the landowners as described by Eqs. (1) and (2). Next we choose some policy instruments that can yield this selection of sites.

4.1. *Selection of forest sites*

First we select those forest sites that all together maximize net social benefits (Eq. (2)) given a constraint on the total area of new forests. The methodology is described in detail in Moons et al. (in press)[8] and follows a heuristic approach. Net social

[6] The marginal cost of public funds (MCPF) measures the distortions caused by the collection of tax revenue. Each euro of collected taxes leads to a direct cost for the taxpayers (that one euro) as well as an indirect cost due to the less efficient functioning of the economy. The tax payments alter the consumption and labour decisions of the taxpayers and influence market behaviour.
[7] This area constraint is a proportional share of the overall Flemish objective of planting 10,000 ha new forests according to the regional surface.
[8] The afforestation problem is a large combinatorial problem solved heuristically. A similar approach taking into account the proximity of population centres was introduced by Jørgensen et al. (1992) who solved the problem using simulated annealing.

benefits subtract all costs from all benefits for all parties involved: landowners, government and society.

Landowners (Eq. (1)) carry the costs of planting and management of the afforestation, manure disposal costs and taxes. They are entitled to the timber yield and the revenues of hunting permits in case of afforestation, to the agricultural yield of the land and agricultural or afforestation subsidies. The government (Eq. (2)) bears the costs of afforestation subsidies as well as the marginal cost of public funds caused by collecting taxes. Society as a whole benefits from afforestation due to recreation, carbon sequestration, other ecological and non-use values created by new forests over and above these values that can be attributed to agriculture. Non-use values are the natural resource values that are independent of people's present use of the resource (Freeman, 2003). These values are said to arise from a variety of motives, including a desire to bequeath certain environmental resources to future generations, a sense of stewardship, and a desire to preserve options for future use. The hypothesis of non-use values has gained wide acceptance among economists working in the field of environmental and resource economics, at least partly as a result of findings of positive non-use values in a variety of settings (Freeman, 2003).

In the application, we assume that all marginal costs, except for manure disposal costs, are constant and all costs are additive. Moreover, we assume that all benefits, except recreation values, of multifunctional forests have constant marginal values and are additive. For non-constant marginal costs and benefits (per hectare and year) there is a geographical interaction between sites. For example, two forests that are located closely together are substitutes since potential visitors will choose between the two.

Recreation benefits of multifunctional forests are highly dependent on the location of the forest, on the location of its substitute forest sites, which can be both existing and other new forests, and on the regional population density. To estimate recreation benefits of non-existing forest sites, we transfer a zonal recreation demand function that was estimated for one base site, i.e. Heverleebos–Meerdaalwoud (HB-MW). This is up until now the only forest for which a recreation valuation study has been conducted in Flanders (Moons et al., 2000). A zonal recreation demand function, or travel cost model, predicts visit rates in view of the cost of a visit (primarily travel costs), socio-demographic data of potential visitors and surroundings of the site (age, education, professional activity, population density) and the availability and characteristics of other forest sites a person might visit (the so-called substitutes). The recreation demand function of HB-MW equals (Moons et al., 2000):

$$\text{Visit rate} = 251 – 3.4\ \text{travel cost} – 0.024\ \text{popden} – 1.16\ \text{subindex} – 774\text{prop}55^{\text{plus}}$$

The visit rate (i.e. the ratio of total visits to the total population) is explained in function of the (two-way) travel cost, the population density within the origin zone (popden), a substitution index (subindex) which measures the total area of substitutes and the proportion of people older than 55 years per origin zone (prop55$^{\text{plus}}$). Next, we transfer the estimated recreation demand function for HB-MW to each of the ten new forest sites in our study region. This gives us an estimate of the number of yearly visits to the new forest site. Further, we calculate the consumer surplus per visit and total recreational value of each forest site. A site may have a different recreation value in the different sets it belongs to due to the varying number of substitutes (Moons et al., in press).

4.2. *Choice of policy instruments*

Having established the optimal location of new forests, the regulator needs to implement a policy and select the most cost effective instrument that will yield this optimal combination of forests. The simplest solution, which is the command-and-control or CAC solution, consists of telling the landowners of the optimal sites to plant forests or face severe penalties. However, this is not a realistic option in a democracy and, for this reason, we examine several other policy options.[9] Also, a scenario including expropriation is very unlikely due to the high political costs and will, therefore, be excluded from our case study. We consecutively discuss five possible policies for afforestation in Flanders.

4.2.1. *Option 1: Purchasing policy at market prices*

More realistically, we can assume that whenever pieces of land specified in the optimal location are put up for sale, the government buys them. This can be realised by a system including rights of first purchase. A *right of first purchase* implies that the Flemish government can buy parcels, which are put up for sale, instead of the highest bidder at the price and conditions specified by this potential buyer. This only happens on condition that there are no other rights of first purchase since tenants or land consolidation committees always have priority. Notary's offices are obliged to give the Flemish government the opportunity to employ its right of first purchase.

To obtain the optimal location of forests, the government should only buy land that is part of the optimal combination. This implies that the government needs to wait until these parcels are put up for sale. In our application, we assume that each period parcel i is put on the market with an exogenous probability p_i. This probability is determined, among other things, by the farmer's need for cash, by retirements or inheritances and also by the farm's income relative to the offered price. In the first period, the government has thus a probability of $\Pi_{i \in \text{OPT}}\, p_i$ of acquiring the optimal location for the forest expansion; with OPT the set of all parcels belonging to the optimal combination. Obviously, it can take a very long time to optimally create forests using this instrument. It is also a rather expensive way of acquiring the desired forests since the government pays market prices. Moreover, the government becomes owner of the lands and needs to manage and maintain them.

4.2.2. *Option 2: Subsidies for specific locations*

Can the government decide to only subsidise forests planted at the optimal locations? Subsidies are only legally binding when written down in a law, which determines the necessary

[9] Since private forestry in Flanders is dominated by small-scale planters, we do not consider tax exemptions as a policy option.

requirements that need to be fulfilled in order to apply for the subsidy. These conditions need to be objective criteria[10] and citizens who meet them cannot be excluded arbitrarily (discrimination principle). It is, nonetheless, possible to specify a total budget and work on a 'first come, first serve' basis. It is, therefore, not legally possible to only subsidise the owner of parcel X on an individual basis and not the owner of parcel Y.

Given the optimal location of forests, the optimal subsidy policy would be:

$$\begin{aligned} s^f &= \max_{i \in OPT}\{Y_i^{agr} - Y_{ij}^{for}\} \text{ for } i \in OPT \\ &= 0 \text{ for } i \notin OPT \end{aligned} \tag{3}$$

with Y_i^{agr} net income if the land is used for agriculture ($Y_i^{agr} = Y_{i0}^a + s_{i0}^a + Y_{i0}^h - C_{i0}^m$) and Y_{ij}^{for} net income if a forest is planted ($Y_{ij}^{for} = Y_{ij}^h + Y_{ij}^t - C_{ij}^m - C_{ij}^p$).[11] This optimal subsidy policy cannot be specified as such since 'belonging to the optimal combination' is not a general and objective criterion. The government can, however, specify the criteria for afforestation subsidies with the view of matching the optimal location as closely as possible. For this reason, it is interesting to look closely at the factors (population density, soil conditions, type of farm…) determining the optimal location.

McCarthy et al. (2003) note that upfront payments paid in the early years of planting may be both a persuasive and cost efficient method of increasing the level of private forestry planting. This is because the planters receive the payments immediately and they do not suffer from any risk of changes in government policy or from devaluation due to inflation.

4.2.3. *Option 3: Subsidy scheme combined with purchases*

Mimicking the current policy in Flanders, the government could also decide to combine the subsidy scheme for specific locations with a purchasing policy. This provides the option to buy certain parcels of land and convert them into forests, if the current landowners are unwilling to use the subsidies provided.

4.2.4. *Option 4: Subsidy and tax scheme*

The Flemish government can also combine subsidies with taxes. They can provide a subsidy to the farmer who decides to plant a forest. If, on the other hand, the land is used for agriculture, then the farmer has to pay a tax proportional to the number of hectares that were not forested. The conditions for the subsidy can depend on various factors such as the distance to existing forests or the soil type. Using this policy would reduce the costs to the government substantially because it also creates tax revenues.

Formally we have, on the one hand, if the farmer decides not to plant a forest, a tax t_{i0} to be paid. On the other hand, if a forest is planted, a subsidy s_{ij}^f for $j \notin \{1,2\}$ is granted. We also assume that $t_{i1} = t_{i2} = s_{i0}^f = 0$. The following conditions must hold to obtain the optimal location of forests:

$$\begin{aligned} Y_i^{agr} - t_{i0} &\le Y_{ij}^{for} + s_{ij}^f \quad \text{if } i \in OPT \\ Y_i^{agr} - t_{i0} &> Y_{ij}^{for} + s_{ij}^f \quad \text{if } i \notin OPT. \end{aligned} \tag{4}$$

A possible solution for the tax and subsidy rate is for $j \in \{1,2\}$:

$$\begin{aligned} s_{ij}^f &\ge Y_i^{agr} - Y_{ij}^{for} \quad \text{if } i \in OPT \quad \text{and} \quad & t_{i0} &< Y_i^{agr} - \max(Y_{i1}^{for}, Y_{i2}^{for}) \quad \text{if } i \notin OPT \\ &= 0 \quad \text{if } i \notin OPT & &= 0 \quad \text{if } i \in OPT. \end{aligned} \tag{5}$$

It is only possible to obtain these tax and subsidy rates if the optimal parcels are distinguishable from non-optimal parcels using objective criteria (see also Option 2).

4.2.5. *Option 5: Auctions*

Auctions are a method frequently used in procuring commodities for which there are no well-established markets. They are of particular interest for conservation contracting (Latacz-Lohmann and Van der Hamsvoort, 1997), since the traded item, the provision of environmental benefits, is a public-type non-market good which has no standard value. Auctions also enable the participants to deal with uncertainty about the object being sold.

In a discriminatory first-price sealed-bid auction farmers can ask the amount of subsidies (= bid) they would like to receive for converting their farmland into forest. This implies that the *n* lowest bidders are rewarded and receive the payment stated in their bids. The regulator will need to set a maximal acceptable bid to induce farmers to reveal their bids truthfully (Myerson, 1981). After all bids are made, the regulator will calculate the optimal cluster of new forests and accept the bids of all landowners that belong to the optimal combination. The farmers do not know in advance the outcome of this optimisation exercise and assume that the probability distribution of winning the auction is equal for all participants. Calculating the optimal location of new forests implies that the government knows the costs and benefits of forestry and agriculture for the different farmers. Landowners, who ask more subsidies than necessary to cover the costs of conversion, will have a zero probability of having their bid accepted. Since it is irrational to bid less than the land conversion costs, farmers will in equilibrium bid precisely enough to cover their costs (Latacz-Lohmann and Van der Hamsvoort, 1997):

$$b_i = Y_i^{agr} - Y_i^{for}. \tag{6}$$

These bids allow the government to reach the optimal combination of forests at lower cost than through subsidies.

5. Data

The study area in this paper is Wetteren–Aalst, a suburban region in East Flanders. Ten agricultural sites are marked as potential locations for new forests. For reasons of simplicity, we assume that the ten sites are each owned by one single farmer[12] and that decisions on land use change apply to the site in its entirety. The farmer might have farmland on other locations or might have cowsheds, sties or folds that are not

[10] The criteria used to allocate the subsidies need to be effective, i.e. they need to promote the goal of the subsidy policy. They also need to be general, i.e. not specifically tailored for one case.

[11] We assume that the agricultural income from grazers and pigs is fixed throughout the whole exercise.

[12] This is reasonable since the average farm size in East Flanders is approx. 30–40 ha.

affected by the afforestation of the farmland in our dataset. For more site information see Appendix A.

We rely on GIS (geographical information systems) for data collection and input. This is the case for the selection of the new forest sites, the distances between sites, the manure disposal and socio-economic characteristics. Other data are derived (or transferred) from relevant Flemish studies or databases where possible.

Each selected site is either planted with poplar (with a rotation cycle[13] of 25 years) or is laid out as a sustainable managed multifunctional forest (with a rotation cycle of 150 years). In the reference scenario all parcels are put to an agricultural use. All costs and benefits for all parties – landowners, society and government– and for all three types of land use are calculated as annuities over a period of 150 years, the chosen rotation cycle (Garcia Quijano et al., 2005). All figures are in EURO 2000 and we use a discount rate of 2.5%.

5.1. *Setting*

In line with policy objectives, 150–200 ha of new forestland is allocated to the region Wetteren–Aalst. All subsets of ten sites within the region that meet this area constraint are compared with respect to their net social benefits. Over 24,000 subsets of at least 2 and at most 7 sites (sites can be either poplar or multifunctional forests) meet the constraint.

As all new forests will be planted on agricultural land, net social benefits of forests need to be compared with the value of the current agricultural use of the land. Three branches of agriculture are present in our dataset: crop farms, crop combined with pig farms, and crop combined with grazer (excl. dairy cows) farms. For ease of exposition, we use the terms pig farms and grazer farms for the last two categories. Net income differs substantially according to the branch of agriculture a site currently belongs to.[14] Crop farms create the highest yearly net income (647 Euro/ha), followed by pigs (549 Euro/ha) and grazers (473 Euro/ha). The net private income includes agricultural subsidies and excludes taxes. Other costs include implicit wages for the farmer, wages paid to third parties, machinery depreciation, maintenance, purchased and self-produced feed, seeds, pesticides, fertilizers, capital costs (CLE, 2000).

Excessive manure production is a serious environmental problem in a densely populated area such as Flanders. Use of the soil for agricultural production allows limited spread of manure on the agricultural land.[15] Manure standards have become more stringent over the last decades. Emission limits for nitrogen and phosphate differ per parcel of land in function of soil type and type of crop, as well as protection laws for area and ground water. The measures included in current Flemish manure policy can be divided into three categories: measures aiming at the source of the problem, instruments to improve fertilizer use and finally manure processing and export (Vervaet et al., 2004).

The manner in which the farmers dispose of the manure produced is therefore important. We assume that grazer farms are able to spread their manure on their own land. Their manure deposition costs are therefore assumed to be zero. Crop farms do not produce any manure (Appendix A). Pig farms, in contrast, cannot spread all produced manure on their own land. We assume that they have an agreement with crop farms to spread their excess manure on cropland. The cost associated with spreading fertilizer on cropland equals the transportation cost and we assume that the cost of one trip by tractor of 10 tonne manure equals 12 Euro.[16]

We assume that, when the farmland is afforested, farmers lose all their agricultural income from that piece of land. As other parcels of farmland or stables owned by the farmer are unaffected, part of the farmers' income will be preserved. Manure produced by grazers and pigs is spread on remaining agricultural land or disposed of in an alternative way, both of which are costly. If farmers are no longer able to spread their manure on land due to afforestation, the cost of industrial processing equals 12 Euro/tonne. Including the processing of manure into the model, implies that the farmers' afforestation decisions cannot be examined independently of each other. If crop farmers decide to plant trees on their land, there will be less land available for spreading the pig manure and pig farmers will have to dispose of their manure in another, more costly, way. Since crop farmers do not consider this externality when deciding on land use, their decisions are not always socially optimal.

If the site is afforested, a farmer's income will depend highly on which other sites are afforested due to the change in available land for spreading manure. It might even become negative once more expensive industrial processing of manure is necessary. The lowest (highest) net private farmer's income is −4738 Euro/ha (544) and year for a pig farm, −1259 (473) for a grazer farm and −364 (647) for a crop farm. The net income per hectare of land of a crop farmer is constant as he does not have any manure to dispose of and is thus independent of the afforestation decisions of other sites.

Besides agricultural products, agrarian land produces benefits such as recreation, hunting, carbon sequestration, non-use and ecological values. Hunting values for agrarian land amount to 8 Euro/ha and year (Moons et al., 2000). Carbon uptake was simulated for agricultural land by Garcia Quijano et al. (2005). As agriculture serves as the benchmark land use, we assume a zero value for carbon sequestration. For data on recreation, non-use and ecological values of agrarian land, very few sources are available. We use data from a Swedish contingent valuation study from 1992 (Drake, 1992). He studies open and varied agrarian landscapes and finds an annual value of 193 Euro/ha and year for recreation, non-use and ecological values combined.[17]

Depending on the afforestation policy scheme, the farmer either receives a subsidy for afforesting the land himself or he sells it to the government. We assume that the price for a

[13] We assume a constant rotation cycle. However, recent literature suggests that the optimal rotation cycle can be influenced by afforestation policies (Tassone et al., 2004).

[14] See CLE (2000).

[15] On average 27 tonnes can be spread on one hectare of agricultural land in East Flanders.

[16] We assume that the fuel use of a tractor is 0.5 liter per km (Rathwell et al., 2000), that the price of diesel is 0.3 Euro/l, that the other costs equal 1.05 Euro/l (Rathwell et al., 2000) and that the average trip is 10 km.

[17] Annuity, Euro 2000.

hectare of farmland in East Flanders is 25,000 Euro.[18] In the latter case, the government is responsible for all costs and entitled to all future yields, in the former case both costs and yields accrue to the farmer who is still the landowner.

5.2. *Alternative land uses*

We discuss two types of land use: poplar and sustainable multifunctional forests.

5.2.1. *Poplar forests*

A site is planted with the best available poplar clones and managed according to the best available management scheme (see also Garcia Quijano et al., 2005). We assume a 25-year rotation cycle. For reasons of comparability, we assume six consecutive rotations with a total duration of 150 years.

Timber yields depend on the type of soil and on average amount to 202 Euro/ha and year (Garcia Quijano et al., 2005). Other types of benefits produced by poplar forests include hunting (8 Euro/ha and year) (Moons et al., 2000), recreation, non-use and ecological values (320 Euro/ha and year) (Drake, 1992). The value per tonne of carbon sequestered is estimated at 10 Euro (CIEMAT, 1999). For a total of approximately 29 tonne of carbon sequestered per hectare (Garcia Quijano et al., 2005) compared to 0 tonne of carbon uptake in the benchmark (agricultural land use), this amounts to 292 Euro/ha and year. Planting and management costs accrue to 99 Euro/ha and year (Garcia Quijano et al., 2005).

5.2.2. *Sustainable multifunctional forest*

A sustainably managed multifunctional forest is a forest where wood production is combined with high ecological and recreational values, characterized by long rotations (i.e. 150 years), managed with a thinning frequency of 10 years and regenerated with a group selection system (Garcia Quijano et al., 2005). We assume a former agricultural site is planted with a mixed oak-beech forest, both native tree types. Thinnings begin at age 40 with a frequency of 10 years. Final harvesting takes place in the year 150. Timber yields as well as the sale of (small game) hunting permits are benefits accruing to the landowner. Other non-tangible benefits include carbon sequestration, other ecological values, non-use values and recreation.

Timber yield accrues to 5 Euro/ha and year on average (Garcia Quijano et al., 2005). These values are much lower than for poplar plantings as harvesting takes place at a later point in time. Hunting values for multifunctional forests are twice the value for poplar plantings (15 Euro/ha and year; Moons et al., 2000). Carbon sequestration values amount to 69 Euro/ha and year (or 6.88 tonnes of carbon valued at 10 Euro/tonne; Garcia Quijano et al., 2005; CIEMAT, 1999), other ecological values amount to 52 Euro/ha and year (Garrod and Willis, 1997) and non-use values are estimated at 3860 Euro/ha and year (Moons et al., in press). The average[19] recreation value for each of our ten study sites varies from 314 to 2268 Euro/ha and year.

Planting and management costs are assumed to be 24 Euro/ha and year (Garcia Quijano et al., 2005). This number is quite high compared to timber yield and can be explained by the difference in timing of these costs and benefits. Costs are high at the beginning of a rotation cycle, benefits are high at the end of a rotation.

6. Results and discussion

In reality the implementation of the Flemish forest policy happens at a very slow pace and the policy targets are not being met in time (Dumortier et al., 2005). One possible explanation can be found in Latacz-Lohmann and Van der Hamsvoort (1997). These authors state that farmers in the EU have proved to be reluctant to participate in conservation programs, such as afforestation programs, because they fear that the government will not allow them to alter the management changes after the contracts have expired. In reality, there are also considerable transaction costs associated with the current afforestation policy and this can deter farmers from participating in the program.

6.1. *Selection of new forests*

Applying the methodology explained in Section 4.1 combined with the data from Section 5, we find that the optimal combination of new forests consists of sites 1, 2, 9 and 10.

Sites 1, 9 and 10 are currently used for crop farming whereas site 2 is used for grazing. Despite the manure externality imposed by the afforestation of crop lands, it is still optimal to do so since the loss in manure disposal possibilities (2351 ton) is relatively small compared to the total manure production (34142 ton) of the animal farms (see Appendix A). Moreover, the average recreation value of each of the four optimal sites is higher than the average recreation value over all sites (i.e. 1290 Euro/ha). Site 2 is the largest in terms of surface area (64 ha), while site 9 measures only 22 ha. Population density around sites 1 and 2 is higher than the average for Flanders, sites 9 and 10 are situated in far less densely populated areas. For more information on these sites see Appendix A. Similar to Termansen et al. (2004), we find that the location of sites relative to existing and other new sites as well as to major population centres is crucial.

6.2. *Comparison of policy options*

First we look at the differences in social welfare between the current subsidy policy and the optimal command-and-control (CAC) policy. This command-and-control policy implies that the government orders the farmers belonging to the optimal combination to plant multifunctional forests on their plots and the farmers fully comply. The farmers still own the land and bear all planting and management costs. Secondly, we consider several policy options to implement the optimal combination of forests. Finally, we investigate what happens if transfers between agents are no longer costless.

6.2.1. *Current subsidy policy versus optimal CAC policy*

First we apply the current Flemish subsidy scheme to our benchmark and observe which farmers will participate. For the specified subsidy amounts farmers 1, 9 and 10 decide

[18] This is the average of ten parcels of farmland put up for sale on the largest Belgian real estate website www.immoweb.be. We use the annuity of this value over 25 years at 2.5%, i.e. 1357 Euro/ha.
[19] Average over all combinations a particular site belongs to.

to plant forests. The current subsidy scheme (see Eq. (2) with $s^f_{i1}=765$ Euro/ha, $s^f_{i2}=395$ Euro/ha and $s^f_{i0}=t_{ij}=0$) increases social welfare with 838 969 Euro compared to not having a Flemish afforestation policy. The optimal policy (with $s^f_{ij}=t_{ij}=0$), which ensures that the new cluster of forests is planted at its optimal location, increases this level of social welfare by another 195 983 Euro, i.e. 23%. This implies that the current afforestation policy in Flanders is not optimal and that there is room for improvement.

In order to identify the possibilities for policy reform, we investigate the differences between current subsidy and optimal CAC policy in Table 2. The current subsidy amount, if we model the landowner's behaviour as in Eq. (1), induces only three (out of ten) farmers to plant forests while the optimal policy involves four landowners. Surprisingly the optimal location of forests has a slightly lower recreational value to Flemish consumers than the present policy. However, the increase in non-use, ecological and carbon sequestration benefits compensates for the loss in recreational value under the optimal policy. It is never socially optimal to plant poplar since these forests have only a limited advantage over agriculture and have higher associated costs. The advantages of poplar plantings, however, may increase once their potential for substituting fossil fuel as a source for electricity production is fully acknowledged and their value as carbon sinks increases.

6.2.2. *Implementing the optimal combination*

As we mentioned in Section 4.2 it is not politically feasible in Flanders to dictate to the landowners of the optimal parcels to plant forests. In order to obtain the optimal cluster of forests, we need regulation that respects the Belgian constitution and international agreements. To this end, we look at the different policy options that were previously discussed in Section 3.

First we discuss the optimal purchasing policy. In the empirical exercise we chose the probabilities p_i ad hoc and the probability that the optimal combination of plots is acquired by the Flemish government is zero for our example since we assume that parcel 10 is never put up for sale (Appendix A).

The second policy option looks at subsidies for specific locations. In our illustration, the subsidy for optimal parcels is 911 Euro/ha of multifunctional forest for crop farms and for farms with grazers. This subsidy scheme induces all crop

Table 2 – Comparison between current subsidy and optimal CAC policy

	Current subsidy policy	Optimal CAC policy
Forested area (in ha)	118	182
Number of forests	3 (1, 9 and 10)	4 (1,2,9 and 10)
Type of forests	Multifunctional	Multifunctional
Net farmers' income (euro)	−13 716	−162 209
Government revenue (euro)	−90 266	0
Net recreational value (euro)	473 221	472 663
Net non-use value + net ecological value + net carbon sequestration (euro)	469 729	724 498

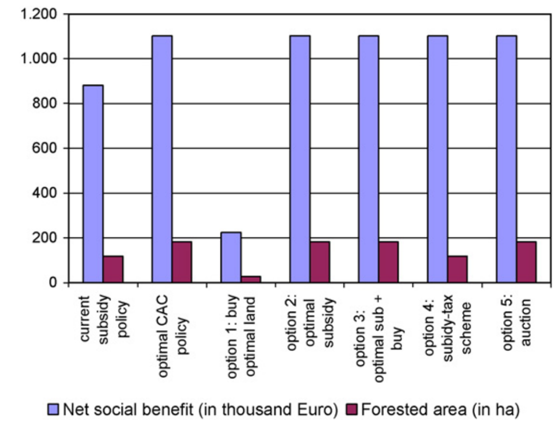

Fig. 1 – Comparison of the different policy options.

farmers (farmers 1, 9 and 10) to plant a forest, while only one grazer farmer (farmer 2) does so ($Y_2^{agr} \le Y_2^{for} + s^f_{21}$). The other two grazer farmers (farmers 4 and 8) do not use the subsidy since they have more manure to dispose of ($Y_{4/8}^{agr} > Y_{4/8}^{for} + s^f_{4/8,1}$). The optimal subsidy is almost 20% more than the current annualised subsidy of 765 Euro/ha (see Table 1).

In the third policy option, we assume that the optimal subsidies from option 2 are complemented with a right of first purchase. We include this option in order to mimic the current afforestation policy, which includes both subsidies and purchases. Given our assumptions, purchasing the land is more expensive for the government than subsidizing afforestation projects. For this reason, the government will only buy the necessary land if the farmer does not participate in the subsidy program.

The fourth option was the revenue-neutral subsidy-tax scheme. If we combine the optimal subsidy from option 2 with a revenue-neutral tax (or a reduction in subsidies) for farmers who favour agriculture, six landowners (1, 2, 4, 8, 9 and 10) would plant forests. This policy specification would, however, not satisfy our area constraint. The resulting forests would cover 243 ha (>200 ha). Therefore, we opt to offer a subsidy of 658 Euro/ha to crop farmers and a revenue-neutral tax of 225 Euro/ha for agricultural land users. This leads to the creation of three forests on land parcels 1, 9 and 10. Note that through this scenario we are able to replicate the (theoretical) result obtained by the current subsidy level, but at lower cost to the government. We are unable to find an objective criterion to induce farmer 2 to cease farming while at the same time convincing farmers 4 and 8 to continue with agriculture. It appears to be impossible to optimally locate the new forests using this policy option and this will lower net social benefits (see Fig. 1).

Finally, the auction scheme induces farmers to exactly ask the amount of subsidies that would allow them to cover their conversion costs of switching from agriculture to forestry. The government can thus reach the optimal combination at a lower cost than through a subsidy scheme. After all, the subsidy needs to be set at the conversion level of the highest cost farmer in the optimal combination ($s^f = \max_{i \in OPT}(Y_i^{agr} - Y_i^{for})$) while an – optimally designed – auction scheme pays each farmer exactly his or her conversion rate ($b_i = Y_i^{for} - Y_i^{for}$ for all $i \in OPT$).

6.3. Costly transfers

We were able to obtain the same level of social welfare with the policy options 2, 3 and 5 as the optimal CAC policy (see Fig. 1). The underlying reason is that subsidies and taxes are treated as costless transfers between different agents. We assume that the government can collect funds at zero cost, i.e. the marginal cost of public funds equals one. Obviously, when we relax this assumption and assume a marginal cost of public funds of 1.5, it becomes important how much a policy costs for the government. Policies that are costless or even raise revenues are preferable to more costly options. This implies that option 4, the subsidy-tax scheme, becomes more advantageous since it is designed as a revenue-neutral policy. However, if the government does not want to tax farmers and since the CAC policy is politically infeasible, the auction policy is the best option. If the auction can be optimally designed, it can substantially decrease government expenditures and increase welfare compared to subsidy or purchasing schemes.

7. Conclusion and policy recommendations

Before deciding on the afforestation policy, it is welfare improving to calculate the optimal location of new forests. The analysis of the optimal location can provide the regulator with objective criteria, which can be used to implement an optimal policy. Currently, the Flemish government supposedly only buys land for forest expansion when a substantial surplus value is expected. However, an objective and clear definition of this substantial surplus value has not been incorporated in existing legislation. Our empirical illustration shows that the welfare gain is considerable if the afforestation subsidy is conditioned on an objective criterion rather than a case-by-case approach.

The calculation of the optimal location of a cluster of forests rather than locating individual forests separately is essential when externalities and interdependencies are present. Recreation benefits, for example, differ according to the number of substitutes available and depend on the location of all newly planted forests. The problem of manure deposition can also lead to negative externalities when farmland is used to spread manure of other farmers. The interactions between existing forests, new forests and agriculture need to be considered in order to correctly calculate the net social benefit of the afforestation policy.

The current subsidy scheme stipulates a minimal area constraint of 0.5 ha. Since recreation seems to be a driving force in the Flemish afforestation policy and given its crucial role in selecting multiple forest combinations, forests should have a minimal area surface of several hectares. The recreation value as well as the ecological value of forests increases dramatically once a threshold of several hectares (20 ha) is crossed. Keeping this in mind, planting uniform poplar forests is less interesting by far than more complex forest structures. When designing a subsidy policy, the regulator should take the asymmetric timing of costs and benefits into account. The largest part of the cost burden falls at the beginning of the forest rotation whereas benefits only start to accrue after several years. The problem of the cost burden can be mitigated by upfront payments of subsidies. To fully capture the benefits, the current planning horizon of 25 years (for a broad leave forest) is rather short. The political planning horizon is likely to be even shorter since the time remaining until the next elections is of critical importance to most politicians. Ideally, the government should consider the whole rotation cycle (of 150 years for a deciduous forest).

It also seems worthwhile to consider auctions for afforestation contracts. This instrument has not been previously used in Flanders but it has proven its worth in the US Conservation Reserve Program (Latacz-Lohmann and Van der Hamsvoort, 1997).

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Appendix A. Main characteristics of the potential forest sites

Site number	(Surface) area	Possible manure disposal (tonne/ha)	Total manure produced (tonne)	Prob. of sale	Population density (15 km zone around land parcel)	Number of substitute forests within km distance (surface area between brackets)				Current land use: agricultural branch
						2	2–5	5–10	10–15	
1	47	19.60	0	0.1	476.47	1 (70)	0	3 (648)	5 (799)	Crop farm
2	64	34.30	2195	0.2	504.82	1 (60)	0	5 (949)	3 (498)	Grazer farm (excl. dairy cows)
3	101	48.91	5379	0.01	511.32	0	1 (179)	0	3 (312)	Pig farm
4	35	35.29	1235	0.05	226.21	0	3 (143)	3 (188)	2 (535)	Grazer farm (excl. dairy cows)

Appendix A (continued)

Site number	(Surface) area	Possible manure disposal (tonne/ha)	Total manure produced (tonne)	Prob. of sale	Population density (15 km zone around land parcel)	Number of substitute forests within km distance (surface area between brackets)				Current land use: agricultural branch
						2	2–5	5–10	10–15	
5	27	302.30	8887	0.03	416.43	0	2 (107)	6 (724)	4 (130)	Pig farm
6	48	156.88	8199	0.15	314.00	0	5 (325)	2 (145)	2 (469)	Pig farm
7	44	133.48	6395	0.02	246.52	0	4 (212)	2 (120)	1 (119)	Pig farm
8	26	71.23	1852	0.1	340.70	0	3 (179)	4 (282)	5 (781)	Grazer farm (excl. dairy cows)
9	22	45.73	0	0.5	154.97	0	2 (137)	3 (175)	1 (62)	Crop farm
10	49	8.73	0	0	263.66	0	3 (175)	3 (157)	1 (119)	Crop farm

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